ABSTRACT

CONTROL OF POLLUTANT EMISSIONS IN NATURAL GAS DIFFUSION FLAMES

Ala R. Qubbaj*
Hashim S. Mahdi
Pedro Lopez
Engineering Department, The University of Texas Pan American
1201 W. University Dr., Edinburg, Texas 78539
Tel: 956-318-5220, Fax: 956-381-3527, E-mail:qubbaj@panam.edu
DE-FG26-00NT40831, 7/1/2000-present

Diffusion flames are employed in most of the practical combustors, such as diesel engines, utility boiler furnaces, gas turbines and aircraft jet engines. Their advantages of the absence of flash back, controlled flammability, ease of burning, and heat release control are the reasons for their dominance. However, the nature of diffusion flames in which fuel and oxidizer enter the reaction zone from opposite directions, results in the unavoidable existence of stoichiometric mixture contour and the consequent high temperature and NO zones. Therefore, diffusion flames were selected to be the subject of this research.

In the present exploratory study, an innovative technique to control pollutant emissions from diffusion flames is numerically investigated. The basic idea behind this technique is controlling the stoichiometry of the flame through changing the flow dynamics and enhancing rates of mixing in the combustion zone with a set of venturis surrounding the flame. A natural gas jet diffusion flame at burner-exit Reynolds number of 5100 was simulated. The general objective of this study is to develop efficient and environmentally superior combustion systems. The specific objective is to numerically investigate the effectiveness and feasibility of the proposed "cascading" technique.

The thermal and composition fields of the baseline and venturi-cascaded flames were numerically simulated using CFD-ACE+, an advanced computational environment software package. The instantaneous chemistry model was used as the reaction model. The concentration of NO was determined through CFD-POST, a post processing utility program for CFD-ACE+. The numerical results showed that, in the near-burner, mid-flame and far-burner regions, the venturi-cascaded flame had lower temperature by an average of 13%, 19% and 17%, respectively, and lower CO_2 concentration by 35%, 37% and 32%, respectively, than the baseline flame. An opposite trend was noticed for O_2 concentration; the cascaded flame has higher O_2 concentration by 7%, 26% and 44%, in average values, in the near-burner, mid-flame and far-burner regions, respectively, than in the baseline case. The results also showed that, in the near-burner, mid-flame, and far-burner regions, the

* Corresponding author

venturi-cascaded flame has lower NO concentrations by 89%, 70% and 70%, in average values, respectively, compared to the baseline case. The numerical results substantiate the conclusion, that venturi-cascading is a feasible method for controlling the pollutant emissions of a burning gas jet. In addition, the numerical results were useful to understand the thermo-chemical processes involved. The results showed that the prompt-NO mechanism plays an important role besides the conventional thermal-NO mechanism.

Since the flow field is the main drive for the changes in temperature and composition, in the present study, the flow field of the baseline and venturi-cascaded flames were numerically modeled; and the axial and radial velocity components were simulated throughout the cascade. The simulated flow field will be used to understand the changes in the temperature and composition fields brought by the venturi-cascade. The results showed a generation of an inward flow (towards the centerline of the jet) over a certain region of the venturi (10 to 30 burner diameters above the base). This change in fluid dynamics accounts for the additional influx of air into the gas jet and explains most of the effect of venturi-cascading on the thermo-chemical structure of the flame. The second phase of the project is to experimentally validate the numerical results which will be pursued as soon as funds become available.